26th International Conference on Computer and Information Technology (ICCIT 2023)

An Attention-Based Deep Learning Approach to Knee Injury Classification from MRI Images

Authored By

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CONTENTS

INTRODUCTION

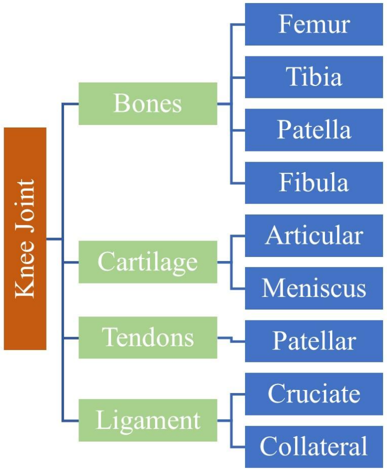

Figure 1: Taxonomy of Knee joint anatomy.

- Knee injuries are among the most common injuries in sports and physical activities.

Symptoms:

- Pain and swelling
- Restricted movement
- Popping or crunching noises

INTRODUCTION(cont'd)

Some Statistics about Knee Injury:

Figure 2: Anterior Cruciate Ligament Anatomy[2].

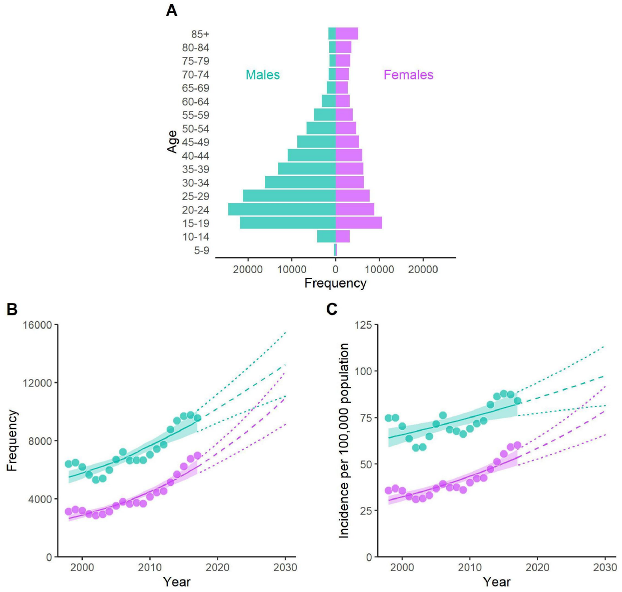

Figure 3: Knee injuries in Australian hospitals (1998-2018). Panel A) Population pyramid of acute injuries over 20 years for males (green) and females (purple) aged 5+; Panel B) Yearly injury frequency for both genders, projected to 2030-2031; Panel C) Yearly injury rate per 100,000 projected to 2030-2031[1].

INTRODUCTION(cont’d)

Different Kinds of Knee Injuries:

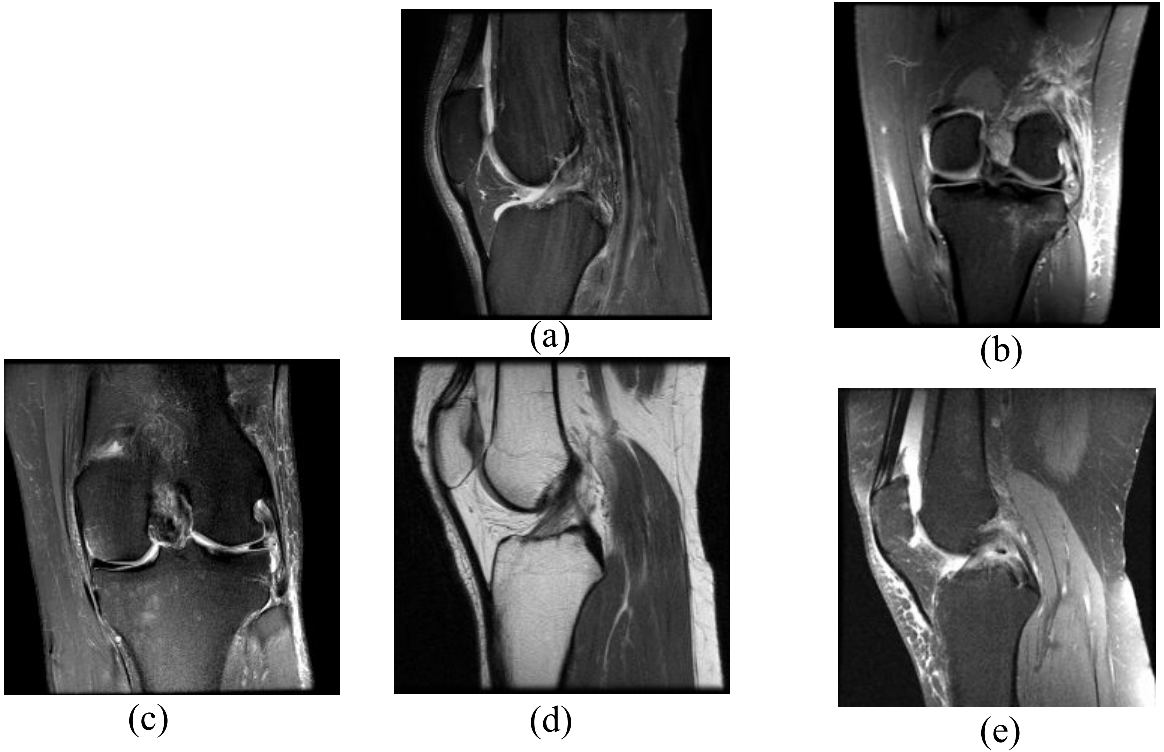

Figure 4: (a) ACL (b) FCL (c) MCL (d) Normal (e) PCL MRI Images

OBJECTIVES

- Get high accuracy on the detection of Knee Injury both Binary and Multi-Class Classification
- Use the Attention Based Module for accuracy improvement
- Compare performance with other models
- Classify MRI images:
    - Binary Classification – ACL and NO_ACL
    - Multi-Class Classification - ACL, PCL, MCL, Normal and FCL

RELATED WORKS

Table 1: Related works Analysis and findings

Related Works	Ref Paper[3]	Ref Paper[4]
Paper Title	A Torn ACL Mapping in Knee MRI Images Using Deep Convolution Neural Network with Inception-v3	Multi-Layered Basis Pursuit Algorithms for Classification of MR Images of Knee ACL Tear
Accuracy	99.04%	95%
Method Used	DCNN based Inception-v3	multi-layered Convolutional Sparse Coding(ML-CSC)
Drawbacks	Overfitting High Training Accuracy – 99.04% Low Testing Accuracy – 95.42%	absence of larger labeled datasets. ▪ Total: 623 MR Images Complete tear – 205 Normal Tear – 205 Partial Tear - 213

METHODOLOGY

DATASET

We have conducted our work into two different datasets:
1. BMEII-AI RedImageNet(Dataset-1) 2. RedImage(Dataset-2)

Table 2: Ground Truth class for DataSet-1(BMEII-AI RedImageNet)

Class	Samples
ACL	569
NO ACL	452

Table 3: Ground Truth classes for DataSet-2 (RedImage)

Class	Samples
ACL	10,085
FCL	466
MCL	7,911
Normal	4,593
PCL	725

PROPOSED METHODOLOGY

Squeeze-and-Excitation Block:

- Squeeze and Excitation Network is a channel-wise attention mechanism that recalibrates each channel accordingly to create a more robust representation by enhancing the important features.

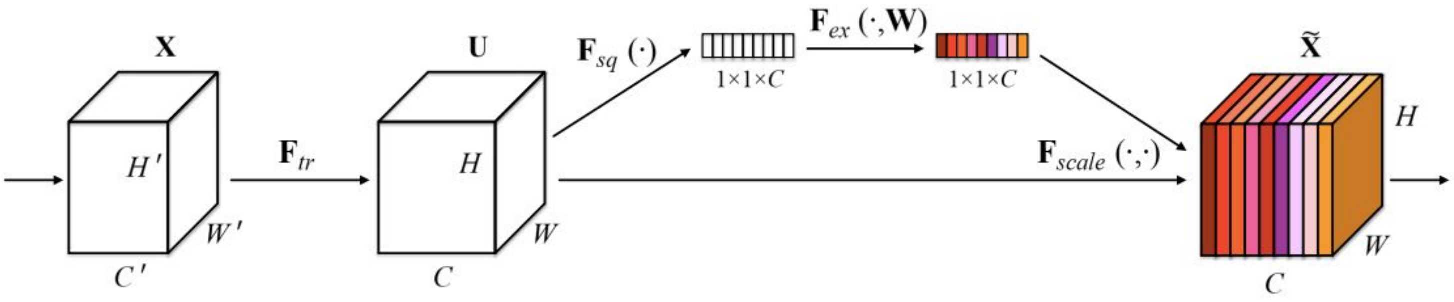

Figure 5: A Squeeze-and-Excitation Block [5].

PROPOSED METHODOLOGY(cont'd)

Squeeze and Excitation Network Detailed Diagram:

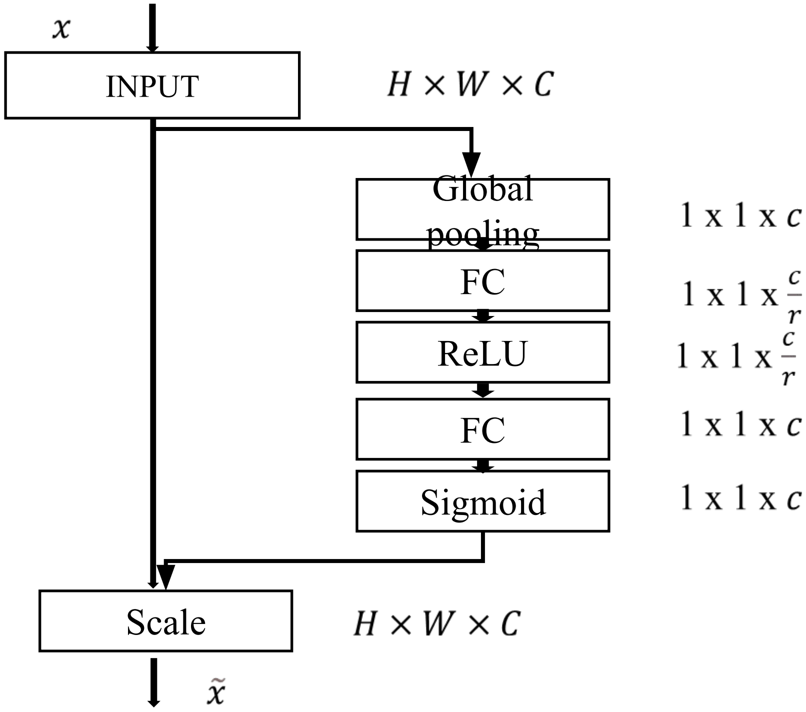

Figure 6: A detailed diagram of the Squeeze and Excitation Network with proper dimensions and the different operations.

PROPOSED METHODOLOGY(cont'd)

CNN architecture for binary and multi-class classification:

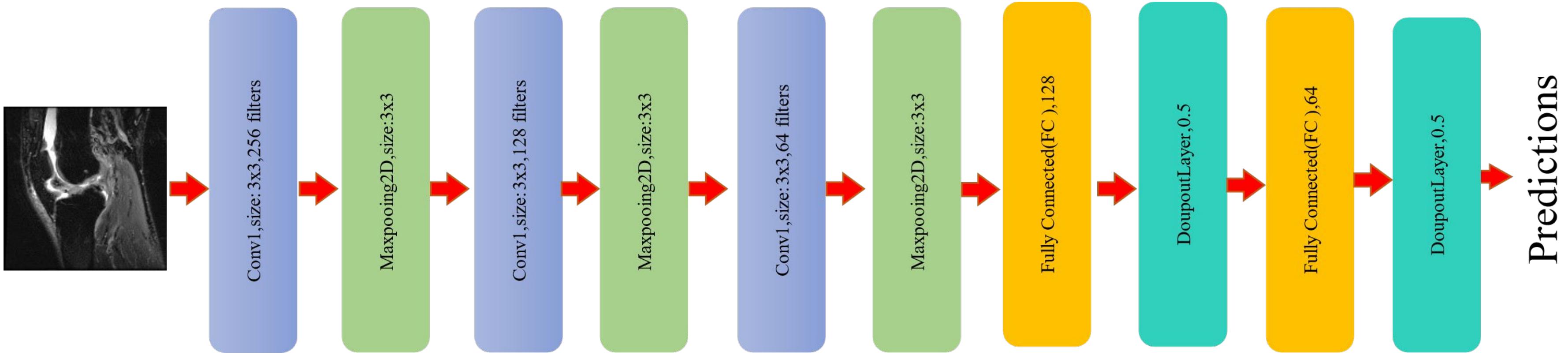

Figure 7: CNN Architecture for Binary Classification for Binary and Multi-Class Classification

PROPOSED METHODOLOGY(cont'd)

Attention-based CNN architecture for binary and multi-class classification:

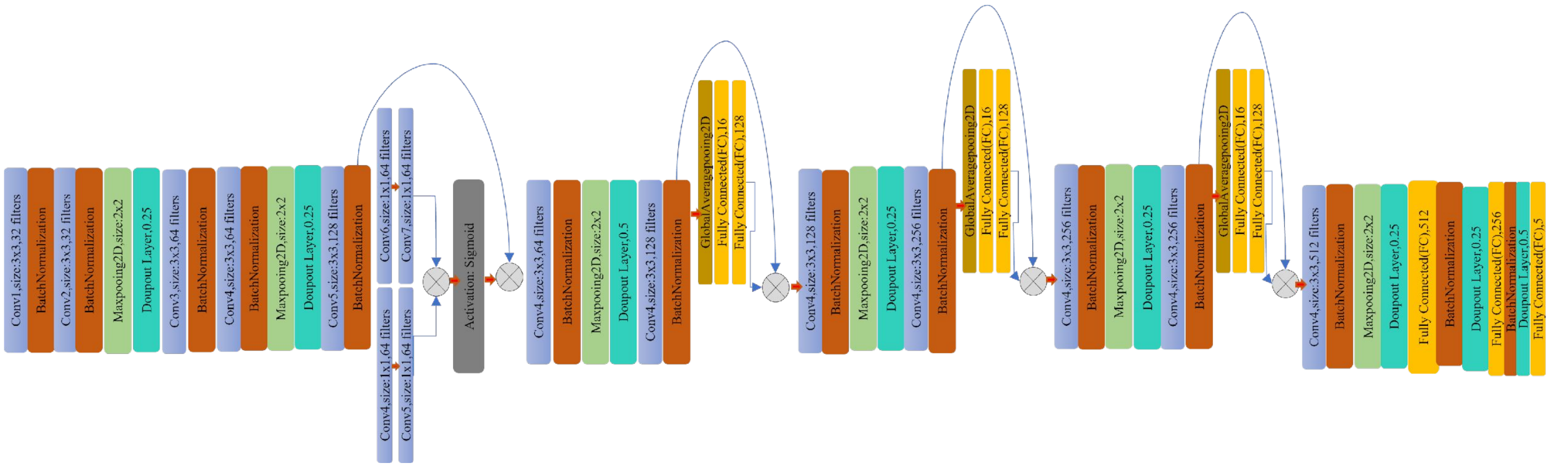

Figure 8:Attention-based CNN architecture for binary and multi-class classification

RESULT ANALYSIS

Curves for Dataset-1(Binary Classification) with CNNs:

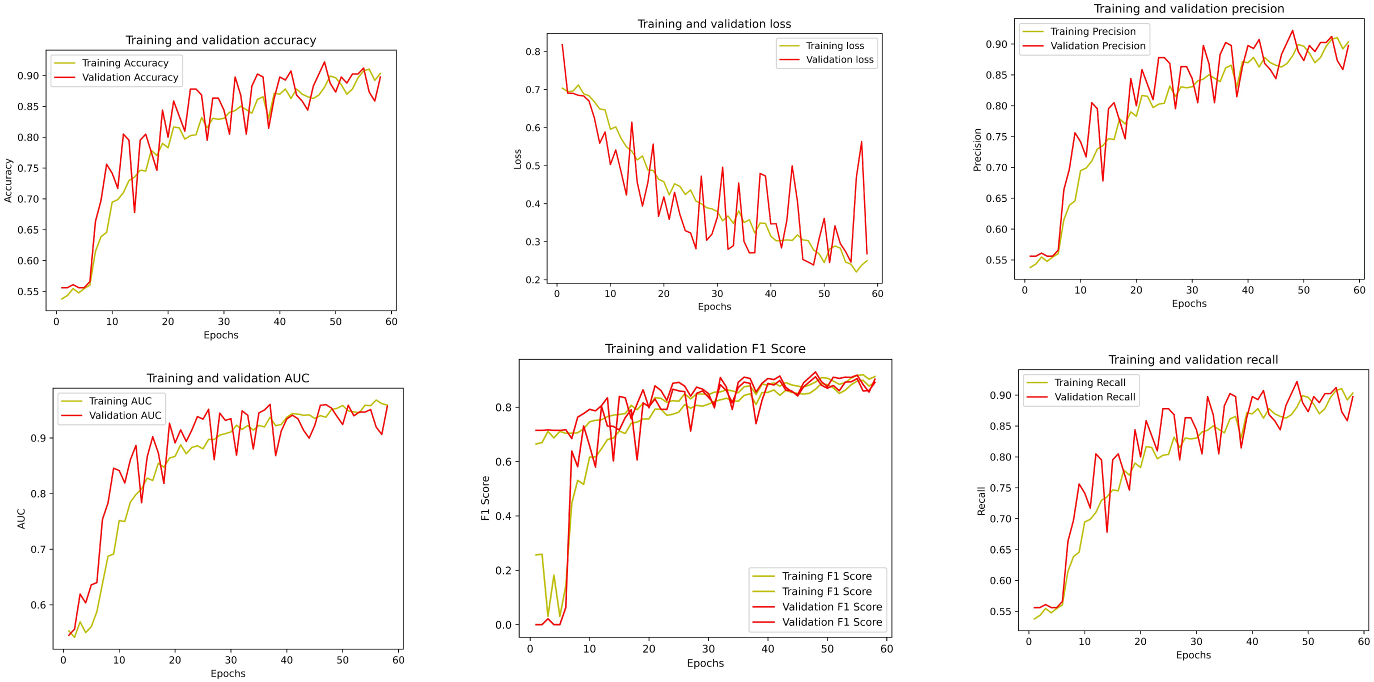

Figure 9: Various Curves for Binary Classification on Dataset-1

RESULT ANALYSIS(cont'd)

Test Results for Binary Classification on Dataset -1 using CNNs:

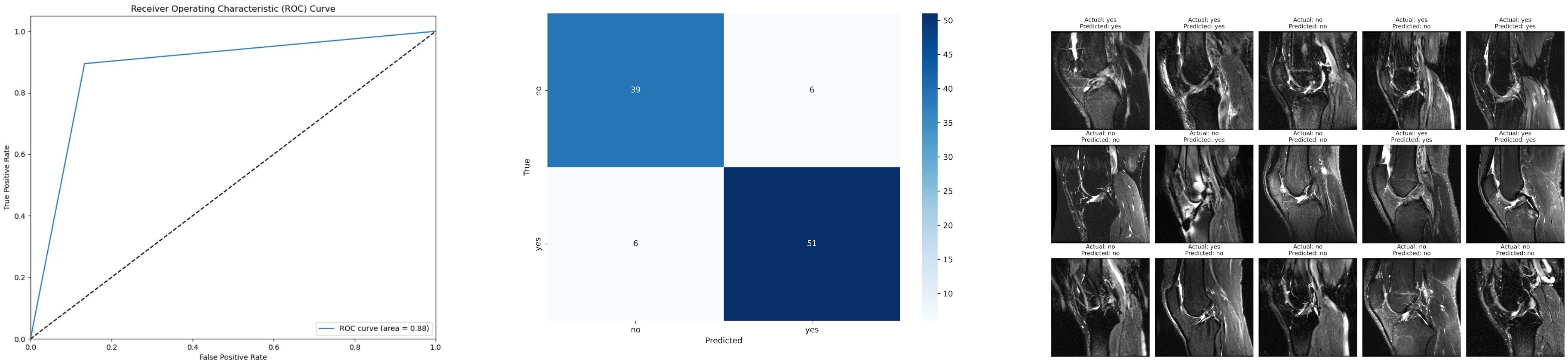

Figure 10: Testing Results for Binary Classification on Dataset-1

RESULT ANALYSIS(cont'd)

Classification Report for Binary Classification on Dataset -1 using CNNs:

Table 4: Test Accuracy Scores for Binary Classification

Metric	Precisoin	Recall	F1-Score	Support
Normal	0.87	0.87	0.87	45
ACL	0.89	0.89	0.89	57
Accuracy	**0.88**			102
Macro avg	0.88	0.88	0.88	102
Weighted avg	0.88	0.88	0.88	102

RESULT ANALYSIS

Curves for Dataset-2(Multi-Class Classification) with

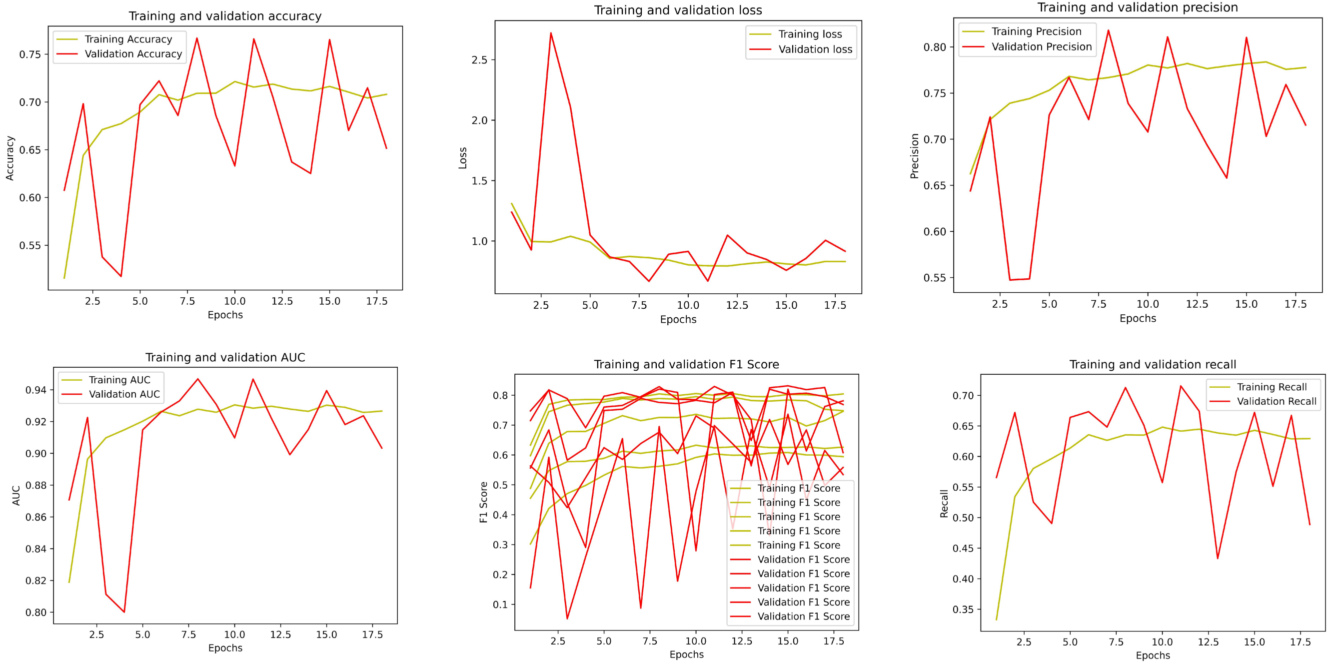

Figure 11: Various Curves for Multi-Class Classification on Dataset-2

RESULT ANALYSIS(cont'd)

Test Results for Multi-Class Classification on Dataset -2 using CNNs:

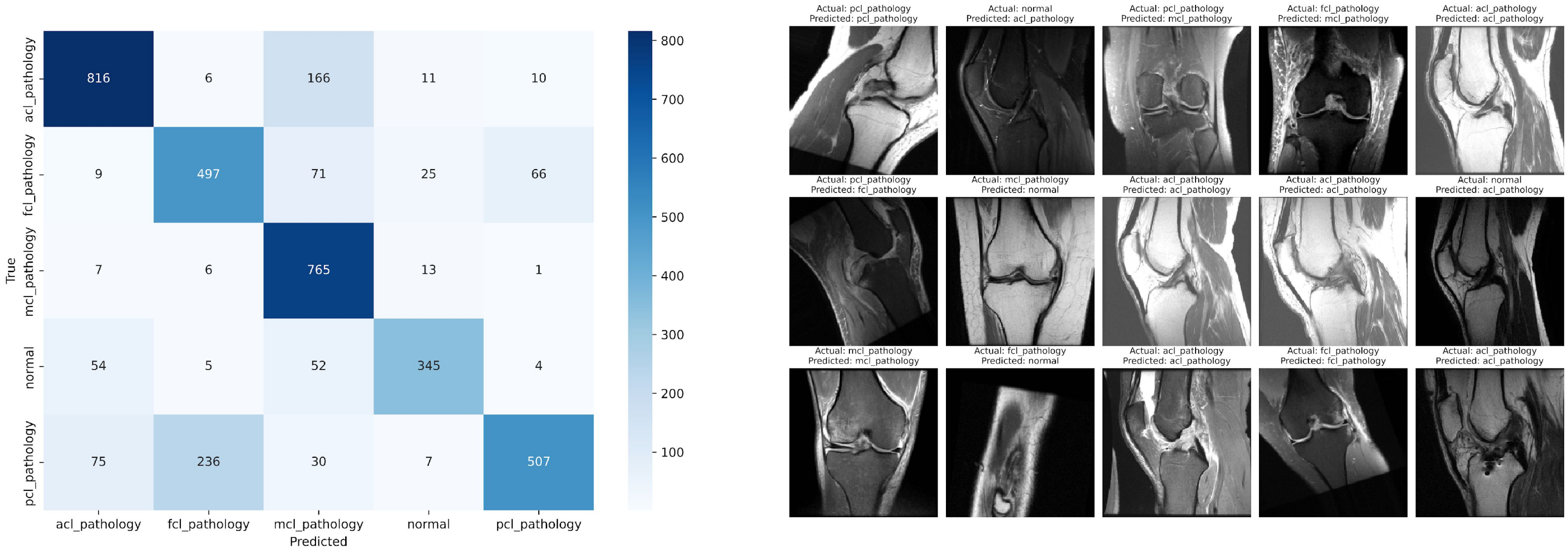

Figure 12: Testing Results for Multi-Class Classification on Dataset-2

RESULT ANALYSIS(cont'd)

Classification Report for Multi-Class Classification on Dataset -2 using CNNs:

Table 5: Classification Report for Multi-Class Classification for Dataset -2

Metrics	Precision	Recall	F1-Score	Support
ACL	0.85	0.81	0.83	1009
FCL	0.66	0.74	0.70	668
MCL	0.71	0.97	0.82	792
Normal	0.86	0.75	0.80	460
PCL	0.86	0.59	0.70	855
Accuracy	**0.77**			3784
Macro avg	0.79	0.77	0.77	3784
Weighted avg	0.79	0.77	0.77	3784

RESULT ANALYSIS(cont'd)

Curves for Dataset-1 (Binary Classification) with Attention Architecture :

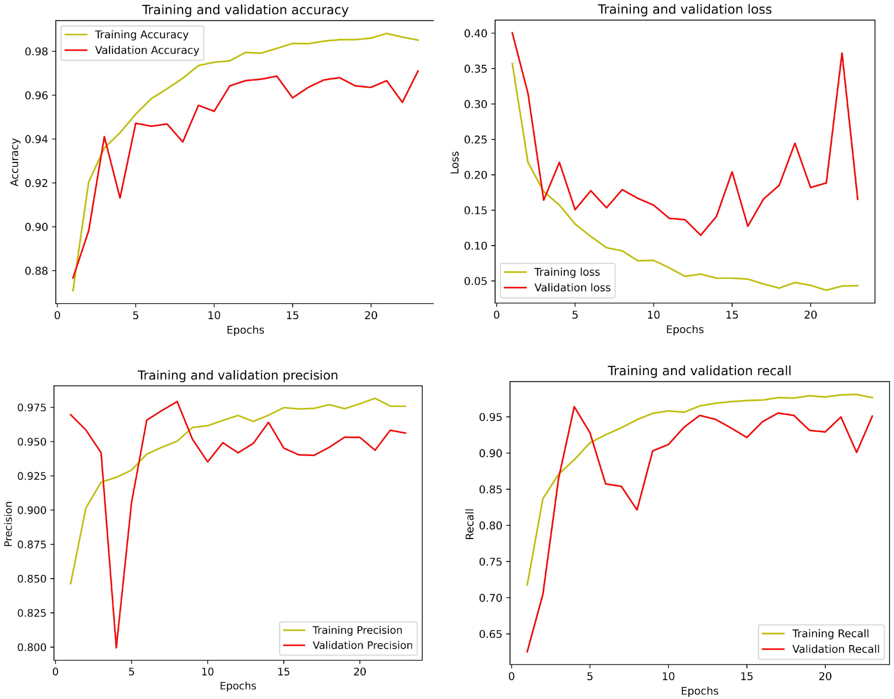

Figure 13: Various Curves and Results for Binary Classification on Dataset-1

RESULT ANALYSIS(cont'd)

Test results for Dataset-1 (Binary Classification) with Attention Architecture :

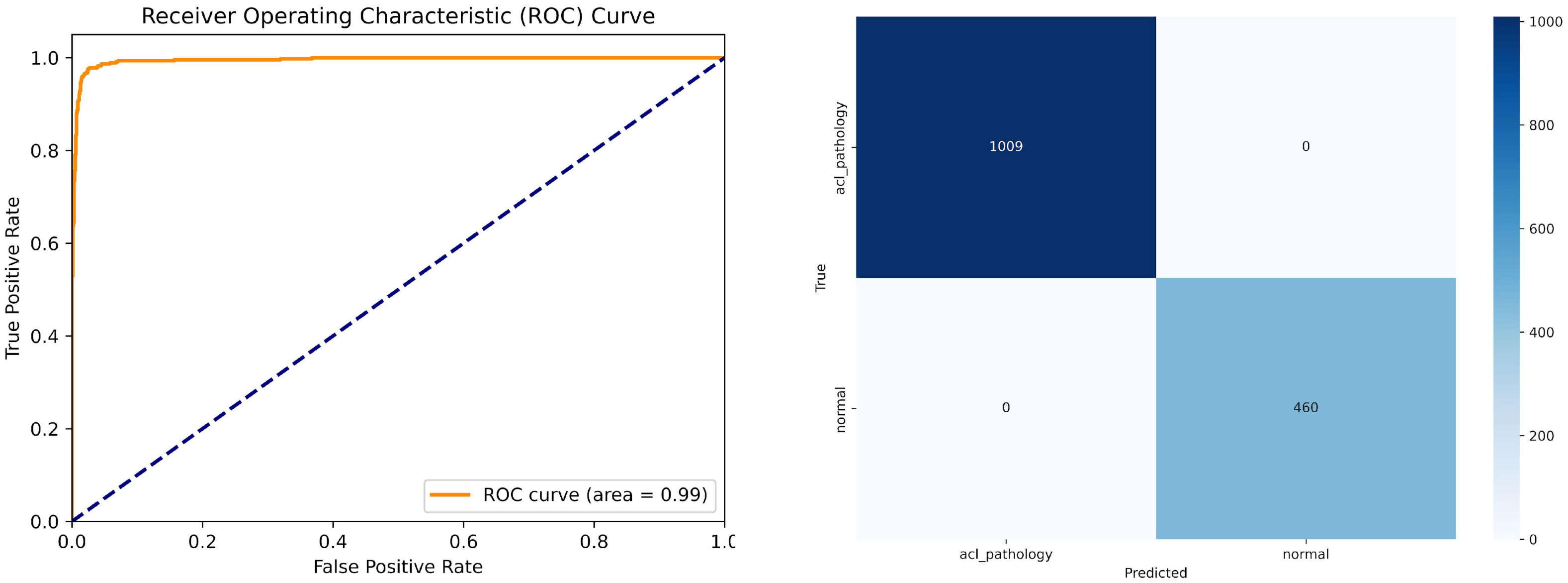

Figure 14: Testing Results for Binary Classification on Dataset-1

RESULT ANALYSIS(cont’d)

Classification Report for Binary Classification on Dataset -1 using Attention Architecture:

Table 6: Test Accuracy Scores for Binary Classification(Dataset-1)

Metric	Precisoin	Recall	F1-Score	Support
ACL	1.00	1.00	1.00	1009
Normal	1.00	1.00	1.00	460
Accuracy	**1.00**			1469
Macro avg	1.00	1.00	1.00	1469
Weighted avg	1.00	1.00	1.00	1469

RESULT ANALYSIS(cont'd)

Multi-Class Classification using Attention Network Architecture (Dataset-2):

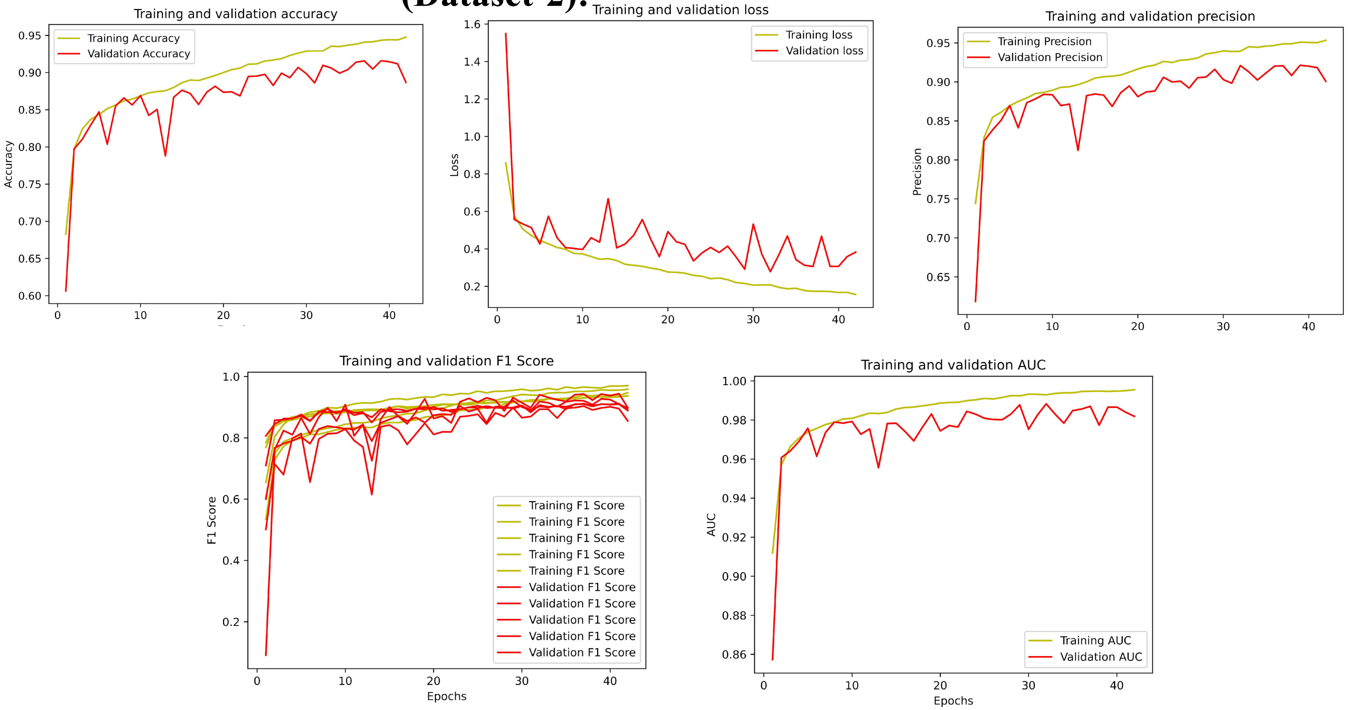

Figure 15: Accuracy, Loss, Precision, F1-Score, and AUC Curves for Multi-Class Classification on Dataset-2

RESULT ANALYSIS(cont'd)

Test results for Dataset-2(Multi-Class Classification) with Attention Architecture :

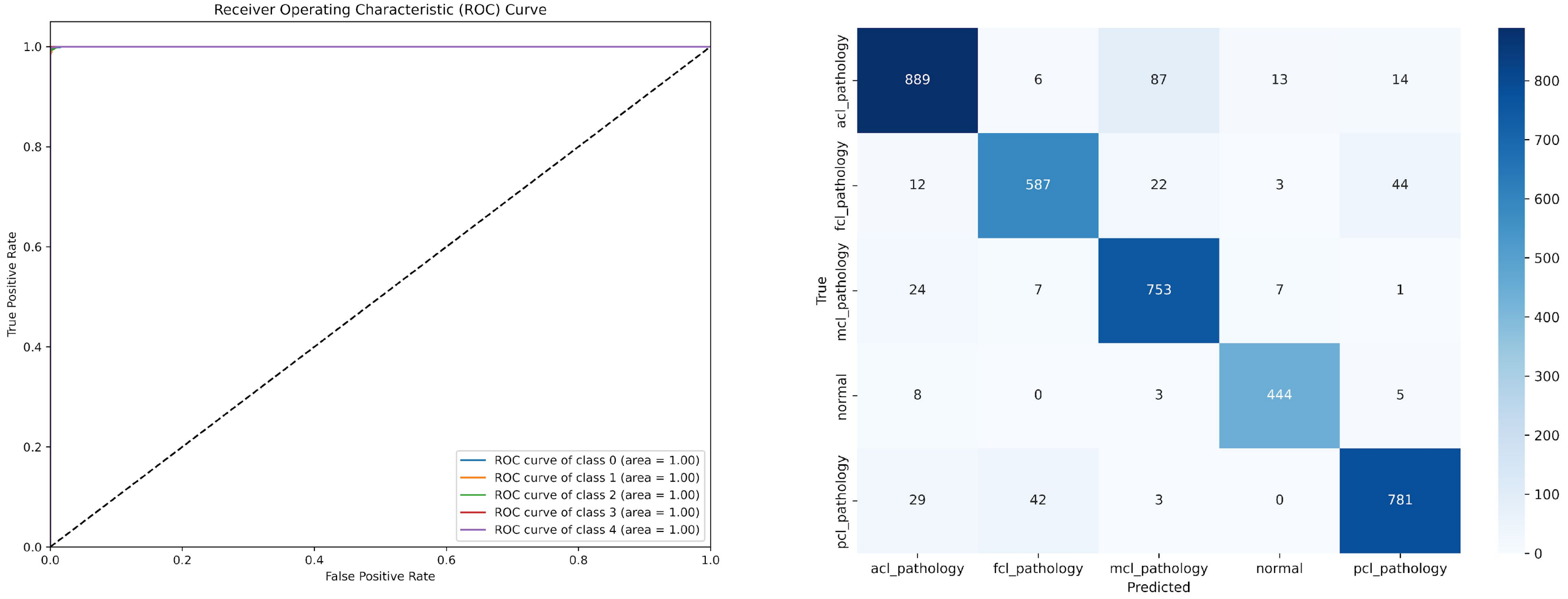

Figure 16: Testing Results for Multi-Class Classification on Dataset-2

RESULT ANALYSIS(cont'd)

Classification Report for Multi-Class Classification on Dataset -2 using Attention Architecture:

Table 7: Classification Report for Multi-Class Classification

Metrics	Precision	Recall	F1-Score	Support
ACL	0.92	0.88	0.90	1009
FCL	0.91	0.88	0.90	668
MCL	0.97	0.95	0.91	792
Normal	0.95	0.97	0.96	460
PCL	0.92	0.91	0.92	855
Accuracy	**0.91**			3784
Macro avg	0.92	0.92	0.92	3784
Weighted avg	0.91	0.91	0.91	3784

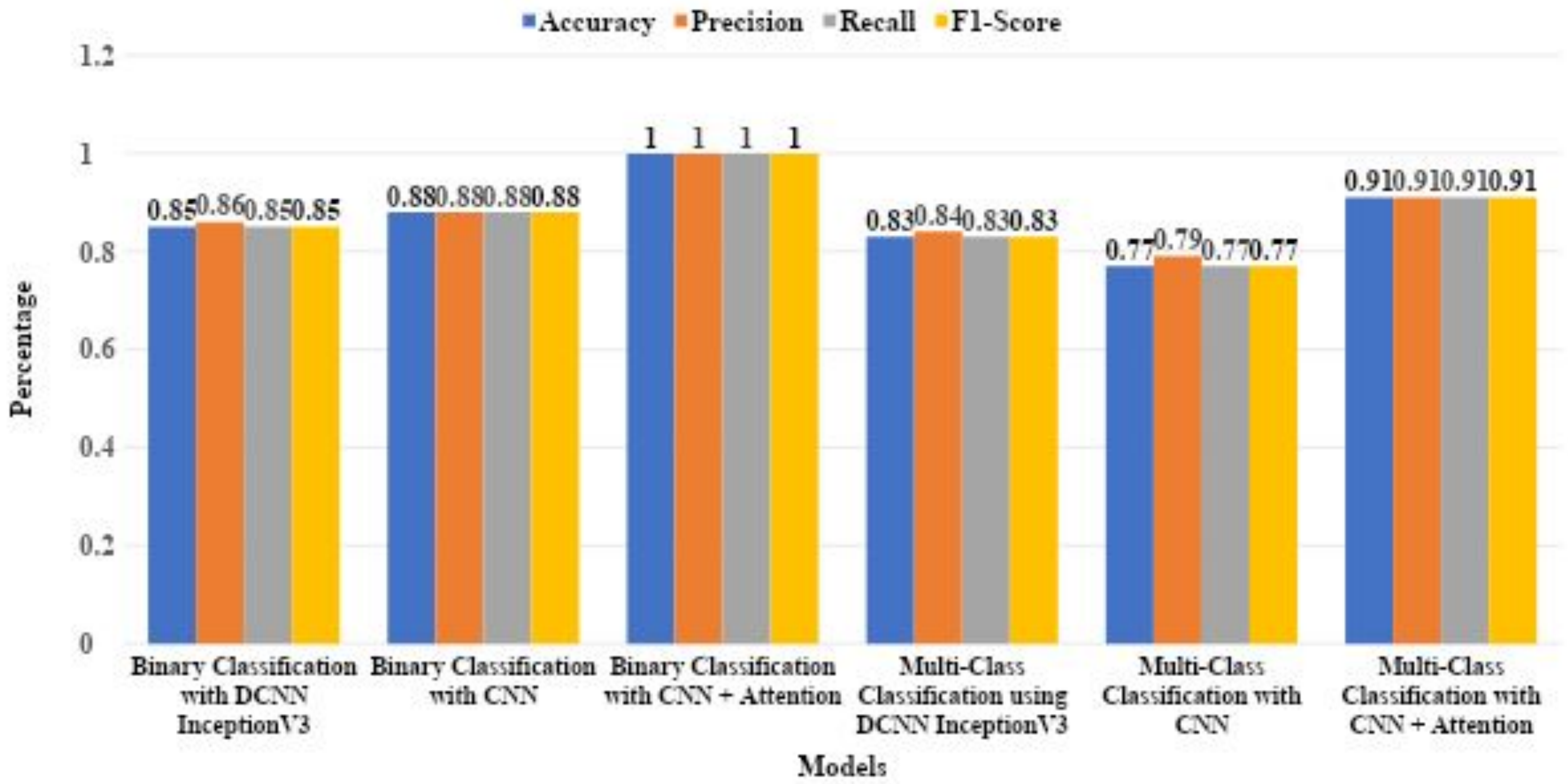

Figure 17: Comparison between various models for binary and multi-class classification.

CONCLUSION

- Our study used the Attention Network for knee injury classification with high accuracy.
- Our Attention Network outperformed the Inception-v3[3] model in binary and multi-class tasks.
- Attention mechanisms enhanced MRI image feature focus, improving accuracy.
- Deep learning, especially custom architectures, can transform diagnostic procedures.

FUTURE WORK

- We plan to add diverse MRI images to test our model's robustness further.
- Integrating techniques like transfer learning or GANs might enhance our model's performance.
- We're focusing on enhancing model interpretability for clinician trust.
- We'll collaborate with medics for real-world feedback and model refinement.

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Thank You!!